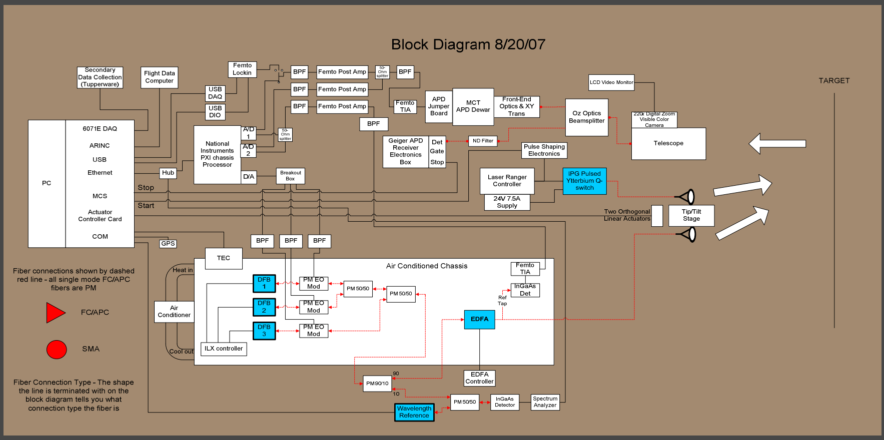
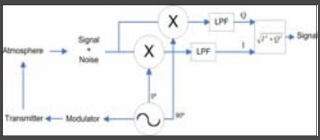
Engineering Development Unit and Validation History

Innovative Low Cost Low Risk Patented Lidar for CO_2, O_2, Topography

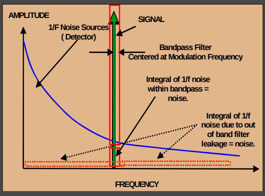
Simultaneous transmission of all wavelengths eliminates significant source of error from fast changes in target reflectivity; reduces pointing requirements, converts most noise to common mode. Use of one receiver chain (for CO2 and O2), and modulation to separate on/off wavelengths eliminates bias and drift which arise with separate optical paths, detectors, and electronics.



What is Synchronous/Lock-In detection and why use it?



- The optical signal is amplitude modulated at a carrier frequency that is high relative to the highest modulating frequencies to be imposed upon it by the atmosphere-target interaction, and so far removed from low frequency electronic noise sources
- The receiver is tuned to the carrier frequency and the modulating envelope is designed to minimize noise and enhance signal to noise ratio.
- These sensitive lock-in signal detection techniques have been successfully applied by ITT to the problem of chemical detection.
- Lock-in detection provides significant background rejection without requiring an optically coherent receiver.

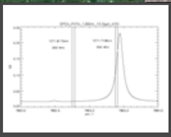


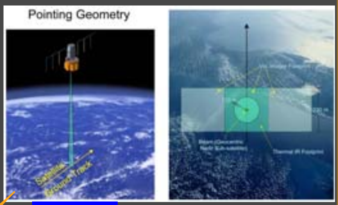
The narrow-band detection method is superior to standard direct detection and achieves very high signal-to-noise-ratios. The result is a power-aperture product that is compatible with small to medium missions.

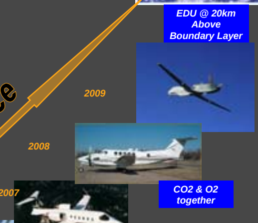
ITT Engineering Development Unit has flown 7 campaigns starting in 2005 and is scheduled for 1 to 2 per year until 2012.

CO2, Topography, O2 (recently added), GPS/INS, On-Board Processing, Real-Time Command and Control and In-Situ CO2, Temp, RH, Pressure Sensors for Validation.

Cloning of CO_2 EDU for retrieval of O_2 (for surface pressure) near 1271 nm completed and preliminary O_2 measurements over 680m horizontal path were made at ITT farm in 2007







Disruptive Solutions to Challenging Missions matured through the principals of:
Voice of Customer
Quality Functional Deployment
and
Value Based Product Development
provide the
Best Performance per $-Risk-Schedule

The authors would like to thank the leadership at NASA LaRC and the Innovative Partnership Program for much needed support of the airborne validation program, AER Inc. for devoting significant internal R&D funds to support this effort and the leadership at ITT Space Systems for their substantial and continued support of this activity.

"Multi-Frequency CW Fiber Laser-Lidar Suite for the ASCENDS Mission"

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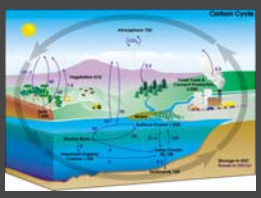
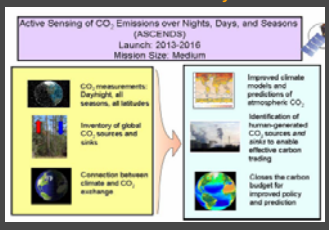
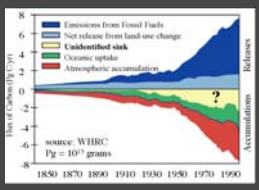
The Carbon Cycle has unresolved and unidentified sinks which are critical to understanding when an equilibrium will be reached, and the resultant impact on modern society.

Where are the sinks? Are they stable? What happens when they shut down? As the Southern Antarctic ocean has this year! Can we create sinks? Do we need to extract and bury CO2 from the Atmosphere?







Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond Earth Science: Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future, National Research Council

Scientific Discovery and Societal Applications SETTING THE DECADAL VISION

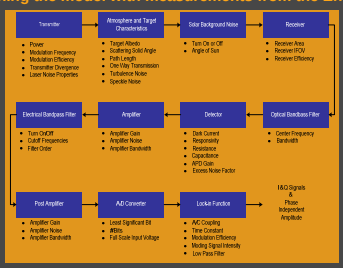
Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability.

"As nations seek to develop strategies to manage their carbon emissions and sequestration, the capacity to quantity the present-day regional carbon sources/sinks and to understand the underlying mechanisms central to prediction of future levels of CO2, and thereby, informed policy decisions, sequestration monitoring, and carbon trading. … A laser-based CO2 mission is the next logical step after the launch of OCO, and it will directly benefit from OCO infrastructure … and hence this mission needs to be launched in the 2013 timeframe at the latest." Quantify global spatial distribution of atmospheric CO2 on scales of weather models. Quantify spatial distribution of terrestrial and oceanic sources/sinks on a1-deg grid at weekly resolution."

Meeting the NRC's Requirements for CO2 Sources and Sinks Requires a Comprehensive Instrument Suite

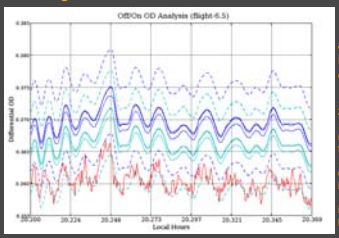
- ➢CO2 Lidar
- ➢O2 Lidar
- ➢PN Laser Ranger
- ➢Passive Temperature Sounder
- ➢Passive CO Sensor
- ➢Context imager

Physics-based, high-fidelity model of the instrument is an essential tool for performing trade studies and error analysis. Combining the model with measurements from the Engineering Development Unit, allows for significant risk reduction…..



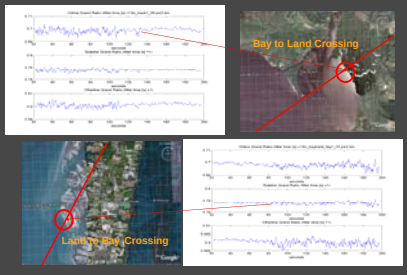
Key Operational Parameters	Airborne	Space
Effective Receiver Area (m2)	0.2	2
Average Transmitted Power (Watts)	5	25
Optical Efficiency (%)	12	40
Detector Temperature	77K	60K

2007 Flight Data and Modeled Data based on in-situ measurements



- ➢Instrument tracks Model and is within uncertainty of in-situ based model comparisons
- ➢The solid red line is the measured 2 second averaged differential OD
- ➢ the solid green lines represent nominal computed differential OD for two atmospheric states
- ➢ the solid cyan line is the modeled OD corrected for aerosol backscatter
- ➢ dotted lines of respective colors illustrate min and max difference based on perturbation calculations.

The ASCENDS CO2 LAS system has proven itself robust to rapid changes in reflectivity. ….

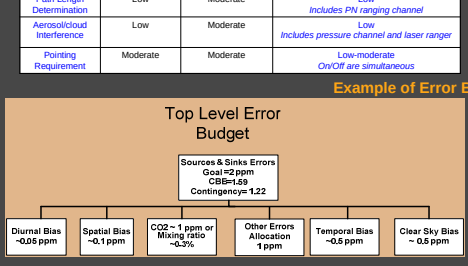


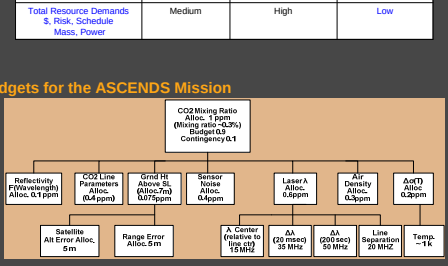
Mission Risk Assessment – adapted from the 'Requirements Definitions for Future DIAL Instruments' report by DLR. (Deutsches Zentrum für Luft- und Raumfahrt e.V.)

Parameter	Risk Level		
	2um Random Modulated IPDA	1.6um Pulsed Direct Detection IPDA	1.5um Narrow Band Lock-in IPDA
Random Error	Low-moderate	Low-moderate	Low-moderate
Systematic Error budget	Moderate-high	Moderate-high	Low-medium *Includes lidar channel at 1.27 for pressure*
Power-Aperture-Area Product	Medium	Low	Medium-high *Is higher than others as it is not range-gated, however, the low cost of 'cots' EDFA & light-bucket, keeps overall cost low.*
Laser Spectral Performance	High	Moderate	Moderate *Demonstrated retrievals with DFB widths and stability.*
Path Length Determination	Low	Moderate	Low *Includes PN ranging channel*
Aerosol/cloud Interference	Low	Moderate	Low *Includes pressure channel and laser ranger*
Pointing Requirement	Moderate	Moderate	Low-moderate *On/Off are simultaneous*

Trade-off Criteria	Risk Level		
	2um Random Modulated IPDA	1.6um Pulsed Direct Detection IPDA	1.5um Narrow Band Lock-in IPDA
Performance Analysis	Compliant with target requirements	Compliant with target requirements	Compliant with target requirements
Technical Aspects Transmitter Rx Optics & Detector Wavelength Control Opto-Mech-Thermal Calibration On-Board Signal Processing	Medium-high Medium Medium Medium Medium Low-Medium	Medium-high High Medium Low-medium Medium-high Low	Low Low Medium Low Medium Low
Total Resource Demands $, Risk, Schedule Mass, Power	Medium	High	Low

Example of Error Budgets for the ASCENDS Mission





Based on the results of over thirty flights and five years of ground testing, we are confident that the architecture is robust, the technology mature, and that the instrument performance model has been validated. Therefore, we have high confidence that the mission studies performed to date are accurate and confirm that the ITT suite meets the NRC's requirements for the space based mission.